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**TARGETED ON-LINE STABILIZED ABSORBENT STRUCTURES**

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**BACKGROUND OF THE INVENTION**

This invention relates generally to nonwoven fabrics made from thermoplastic fibers.

Thermoplastic resins have been extruded to form fibers, fabrics and webs for a number of years. Common thermoplastics for this application are polyolefins, particularly polypropylene. Other materials such as polyesters, polyetheresters, polyamides and polyurethanes are also used to form nonwoven fabrics.

Nonwoven fabrics or webs are useful for a wide variety of applications such as personal care products, towels, recreational or protective fabrics and as geotextiles and filter media. The nonwoven fibers used in these applications may be made by many processes known in art, such as spunbonding and meltblowing. Nonwoven fibers they may be processed into webs through bonding and carding processes, airforming (airlaying), and other processes.

Fibers are commonly consolidated to form a web by adhesive, ultrasonic, thermal, and mechanical bonding. These processes work well but have individual idiosyncratic drawbacks. Adhesive bonding and hydroentangling, for example, necessitate the removal of water, a process involving the addition of more energy for a rather lengthy time. Ultrasonic bonding is also an energy intensive activity involving energy being added somewhat randomly to a web. Thermal bonding also involves the addition of energy to the web in a relatively slow process to melt particular binder fibers.

A nonwoven fabric wherein the binder fibers had an additive that would aid in the energy absorption of the fibers so they could be heated more rapidly to their melting temperature, would be very advantageous for high-speed industrial applications. The

difficulty is in composing the specific blend of materials for the binder fibers that will absorb sufficient energy at line speeds so as to create the appropriate absorbent structure. This approach requires very highly selective "lossy" materials (i.e., materials with a high dielectric loss), in the form of fibers, which are capable of converting

5 microwave energy to heat in order that melting occurs at specific bond points within the absorbent structure. The difficulty is in finding and creating materials with sufficient loss or receptivity to electromagnetic radiation.

An improved binder fiber that could reach its melting temperature under the proper conditions in a matter of fractions of a second, with other materials that were of

10 the proper microwave receptivity, would significantly reduce processing and production time and thus increase manufacturing efficiency and reduce product cost. It is an object of this invention to produce such a fabric made from such fibers.

### **SUMMARY OF THE INVENTION**

15 The objects of this invention are achieved by a nonwoven structure having less than 5 times more oxidation at its outer surface than at its center and more particularly less than 3 times more oxidation at its outer surface than at its center. The structure may include superabsorbent, natural fibers and a low melting fiber.

The binder fiber may include an energy receptive additive. The binder fiber of the

20 structure should have a dielectric loss of between 0.5 to 15, more particularly between 1 to 15 and still more particularly between 5 to 15.

The energy receptive additive may be carbon black, magnetite, silicon carbide, calcium chloride and may be present in an amount between 2 and 40 weight percent of said binder fiber, more particularly between 5 and 15 weight percent of said binder fiber.

25 The binder fiber may be a bicomponent fiber of the sheath/core or islands-in-the-sea type. If the fiber is a sheath/core bicomponent fiber the additive may be present in the

sheath or core and if of the islands-in-the-sea type, in either the continuous or discontinuous phase, though the continuous phase is preferred.

The nonwoven structure of claim may have the superabsorbent, natural fibers and binder fibers homogeneously mixed. Alternatively, the superabsorbent, natural fibers and binder fibers may be heterogeneously mixed, more particularly the binder fibers, density and/or thickness may vary in concentration in the X-Y plane or in the Z-direction.

In a particular embodiment, the nonwoven structure may be made from superabsorbent, pulp, and an energy receptive additive in an amount between 5 and 15 weight percent having a dielectric loss of at least 0.5.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

Figure 1 is a graph of the heating depth profiles for infrared/convection versus dielectric heating.

Figure 2 is a graph of the oxidation depth profiles for infrared/convection versus dielectric heating.

### **DEFINITIONS**

As used herein the term "nonwoven fabric, structure or web" means a web having a structure of individual fibers or threads which are interlaid, but not in an identifiable manner as in a knitted fabric. Nonwoven fabrics or webs have been formed from many processes such as for example, meltblowing processes, spunbonding processes, and bonded carded web processes. The basis weight of nonwoven fabrics is usually expressed in ounces of material per square yard (osy) or grams per square meter (gsm) and the fiber diameters useful are usually expressed in microns. (Note that to convert from osy to gsm, multiply osy by 33.91).

As used herein the term "meltblown fibers" means fibers formed by extruding a molten thermoplastic material through a plurality of fine, usually circular, die capillaries as molten threads or filaments into converging high velocity, usually hot, gas (e.g. air) streams which attenuate the filaments of molten thermoplastic material to reduce their diameter, which may be to microfiber diameter. Thereafter, the meltblown fibers are carried by the high velocity gas stream and are deposited on a collecting surface to form a web of randomly dispersed meltblown fibers. Such a process is disclosed, for example, in US Patent 3,849,241 to Butin et al. Meltblown fibers are microfibers which may be continuous or discontinuous, are generally smaller than 10 microns in average diameter, and are generally tacky when deposited onto a collecting surface.

"Spunbonded fibers" refers to small diameter fibers that are formed by extruding molten thermoplastic material as filaments from a plurality of fine capillaries of a spinneret. Such a process is disclosed in, for example, US Patent 4,340,563 to Appel et al. and US Patent 3,802,817 to Matsuki et al. The fibers may also have shapes such as those described, for example, in US Patents 5,277,976 to Hogle et al. which describes fibers with unconventional shapes.

As used herein the term "bicomponent fibers" refers to fibers which have been formed from at least two polymers extruded from separate extruders but spun together to form one fiber. Bicomponent fibers are also sometimes referred to as multicomponent or conjugate fibers. The polymers are usually different from each other though bicomponent fibers may be monocomponent fibers. The polymers are arranged in substantially constantly positioned distinct zones across the cross-section of the bicomponent fibers and extend continuously along the length of the bicomponent fibers. The configuration of such a bicomponent fiber may be, for example, a sheath/core arrangement wherein one polymer is surrounded by another or may be a side by side arrangement, a pie arrangement or an "islands-in-the-sea" arrangement. Bicomponent fibers are taught in US Patent 5,108,820 to Kaneko et al., US Patent 4,795,668 to Krueger et al., US Patent 5,540,992 to Marcher et al.

and US Patent 5,336,552 to Strack et al. Bicomponent fibers are also taught in US Patent 5,382,400 to Pike et al. and may be used to produce crimp in the fibers by using the differential rates of expansion and contraction of the two (or more) polymers. For two component fibers, the polymers may be present in ratios of 75/25, 50/50, 25/75 or any other desired ratios. The fibers may also have shapes such as those described in US Patents 5,277,976 to Hogle et al., US Patent 5,466,410 to Hills and 5,069,970 and 5,057,368 to Largman et al., which describe fibers with unconventional shapes.

As used herein the term "biconstituent fibers" refers to fibers which have been formed from at least two polymers extruded from the same extruder as a blend. The term "blend" is defined below. Biconstituent fibers do not have the various polymer components arranged in relatively constantly positioned distinct zones across the cross-sectional area of the fiber and the various polymers are usually not continuous along the entire length of the fiber, instead usually forming fibrils or protofibrils which start and end at random.

Biconstituent fibers are sometimes also referred to as multiconstituent fibers. Fibers of this general type are discussed in, for example, US Patents 5,108,827 and 5,294,482 to Gessner. Bicomponent and biconstituent fibers are also discussed in the textbook Polymer Blends and Composites by John A. Manson and Leslie H. Sperling, copyright 1976 by Plenum Press, a division of Plenum Publishing Corporation of New York, ISBN 0-306-30831-2, at pages 273 through 277.

"Bonded carded web" refers to webs that are made from staple fibers which are sent through a combing or carding unit, which separates or breaks apart and aligns the staple fibers in the machine direction to form a generally machine direction-oriented fibrous nonwoven web. This material may be bonded together by methods that include point bonding, through air bonding, ultrasonic bonding, adhesive bonding, etc.

"Airlaying" is a well-known airforming process by which a fibrous nonwoven layer can be formed. In the airlaying process, bundles of small fibers having typical lengths ranging from about 3 to about 52 millimeters (mm) are separated and entrained in an air

supply and then deposited onto a forming screen, usually with the assistance of a vacuum supply. The randomly deposited fibers then are bonded to one another using, for example, hot air or a spray adhesive. The production of airlaid nonwoven composites is well defined in the literature and documented in the art. Examples include the DanWeb process as described in US patent 4,640,810 Laursen et al. and assigned to Scan Web of North America Inc, the Kroyer process as described in US patent 4,494,278 Kroyer et al. and US patent 5,527,171 Soerensen assigned to Niro Separation a/s, the method of US patent 4,375,448 Appel et al assigned to Kimberly-Clark Corporation, or other similar methods.

“Personal care product” means products for the absorption of body exudates, such as diapers, training pants, disposable swim wear, absorbent underpants, adult incontinence products, bandages, veterinary and mortuary products, and feminine hygiene products like sanitary napkins and pantliners.

The “dielectric loss” is a measure of how receptive to high frequency energy a material is. The measured value of  $\epsilon'$  is most often referred to as the dielectric constant, while the measurement of  $\epsilon''$  is denoted as the dielectric loss factor. These are measured directly using a Network Analyzer with a low power external electric field (i.e., 0 dBm to +5 dBm) typically over a frequency range of 300 kHz to 3 GHz, although Network Analyzers to 20 GHz are readily available, for example, the 8720D Dielectric Probe available from the Hewlett-Packard Company (HP). By definition,  $\epsilon''$  is always positive, and a value of less than zero is occasionally observed when  $\epsilon''$  is near zero due to the measurement error of the analyzer. The “loss tangent” is defined as the calculated ratio of  $\epsilon''/\epsilon'$ . This loss tangent results as the vector sum of the orthogonal real( $\epsilon'$ ) and imaginary( $\epsilon''$ ) parts of the complex relative permittivity ( $\epsilon_r$ ) of a sample. The vector sum of the real and imaginary vectors creates an angle ( $\delta$ ) where  $\tan \delta$  is the analytical geometry equivalent to the ratio of  $\epsilon''/\epsilon'$ . The application of the mathematical relationships and measurements

discussed allows an estimation of the microwave affinity or microwave-receptivity for a particular material subjected to a microwave field.

### **DETAILED DESCRIPTION**

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Related material is disclosed in U.S. Patent Application Serial No. \_\_\_\_\_  
entitled TARGETED BONDING FIBERS FOR STABILIZED ABSORBENT STRUCTURES  
by F. Abuto et al., (attorney docket No. 15,708); in U.S. Patent Application Serial No.  
\_\_\_\_\_ entitled ABSORBENT STRUCTURES HAVING LOW MELTING FIBERS by J.  
10 Workman et al. (attorney docket No. 15,708B); and in U.S. Patent Application Serial No.  
\_\_\_\_\_ entitled TARGETED ON-LINE STABILIZED ABSORBENT STRUCTURES by F.  
Abuto et al., (attorney docket No. 17,527) and U.S. Patent Application Serial No. \_\_\_\_\_  
entitled METHOD AND APPARATUS FOR MAKING ON-LINE STABILIZED ABSORBENT  
15 MATERIALS by T. Rymer et al., all of which were filed contemporaneously herewith on  
December 20<sup>th</sup>, 2001 (attorney docket No. 16820). The entire disclosures of these  
documents are incorporated herein by reference in a manner that is consistent herewith.

The bonding together of nonwoven webs has been performed by a number of  
processes that involve the addition of energy to the entire web or to bonding of only  
particular points on the web. One common process is thermal bonding wherein the web is  
20 heated until the melting point of one of the component fibers is reached. The melted fiber  
bonds to other fibers in the web as it cools to give the web integrity. This process is slow  
and relatively inefficient, as it involves heating the entire mass of the web to produce, in  
most cases, point bonds. Thermal point bonding through the use of a patterned and anvil  
roller system is an improvement as it delivers energy to specific points, but it remains rather  
25 slow. These devices also require significant maintenance to keep their tolerances within  
specified ranges.

The inventors have found that an energy receptive additive can be included in synthetic fibers during production, and later excited to melt the matrix polymer and so bond the web. This allows the matrix polymer to reach its melting temperature much more rapidly than it would without the additive and allows the fiber bonding in the web to occur at faster

5 rate than without the additive.

In order to be industrially applicable, the energy receptive additive must absorb energy and melt the matrix polymer at the desired frequency of electromagnetic energy (between 0.01 to 300 GHz) very rapidly, in the range of fractions of a second, desirably less than a quarter of a second and at most about half a second. Processes which involve the

10 absorption of energy and bonding of the web in a time as long as 30 seconds are intended to be within the scope of this invention, though the activation time will most likely be on the order of fractions of a second. This melting will depend on a number of factors such as microwave generator power, additive receptivity, and fiber denier, which is generally between 1 and 20, as well as the composition of the matrix polymer.

Synthetic fibers include those made from synthetic matrix polymers like polyolefins, polyamides, polycaprolactones, polyetheramides, polyurethanes, polyesters, poly (meth) acrylates metal salts, polyether, poly(ethylene- vinyl acetate) random and block

15 copolymers, polyethylene -b- polyethylene glycol block copolymers, polypropylene oxide-b-polyethylene oxide copolymers (and blends thereof) and any other suitable synthetic

20 fibers known to those skilled in the art.

The energy receptive additive may be added to a fiber-making matrix polymer as it is compounded, or coated onto the fiber as a sizing after it is produced. A typical method of compounding the additive with the matrix polymer is with a twin screw extruder, which thoroughly mixes the components prior to extruding them. Upon extrusion, the polymer

25 blend is usually pelletized for convenient storage and transportation.

If the fiber is a bicomponent fiber the energy receptive additive may be added to either or both of the parts of the fiber. The energy receptive additive may also be added



to one or more components, preferably the continuous phase, of a biconstituent fiber and so intermittently distributed throughout the length and cross-section of the fiber. If the additive to be used is not compatible with the matrix polymer into which it is to be blended, a "compatibilizer" may be added to enhance the blending. Such compatibilizers are  
5 known in the art and examples may be found in US Patents 5,108,827 and 5,294,482 to Gessner.

Energy receptive additives can be receptive to various specific spectra of energy. Just as a black item will absorb more energy and become warmer than the same item colored white when subjected to the same amount of solar energy, energy receptive  
10 additives will absorb energy at their specific wavelength, directed at them. Fibers with such additives can be used as binder fibers in the production of coherent webs. One method of providing energy to a receptive material is known as dielectric heating.

Dielectric heating is the term applied to the generation of heat in non-conducting materials by their losses when subject to an alternating electric field of high frequency. The  
15 frequencies necessary range from 0.01 to 300 GHz (billion cycles/sec). Heating of non-conductors by this method is extremely rapid. This form of heating is applied by placing the non-conducting material between two electrodes, across which the high-frequency voltage is applied. This arrangement in effect constitutes an electric capacitor, with the load acting as the dielectric. Although ideally a capacitor has no losses, practical losses do occur, and  
20 sufficient heat is generated at high frequencies to make this a practical form of heat source.

The frequency used in dielectric heating is a function of the power desired and the size of the work material. Practical values of voltages applied to the electrodes are 2000 to 5000 volts/in of thickness of the work material. The source of power is by electronic oscillators that are capable of generating the very high frequencies desirable.

25 The basic requirement for dielectric heating is the establishment of a high-frequency alternating electric field within the material or load to be heated. Once the electric field has been established, the second requirement involves dielectric loss properties of the material

to be heated. The dielectric loss of a given material occurs as a result of electrical polarization effects in the material itself and may be through dipolar molecular rotation and ionic conduction. The higher the dielectric loss of a material, the more receptive to the high frequency energy it is.

- 5           Radio frequency or RF heating occurs at about 27 MHz and heats by providing about have the total power delivered as ionic conduction to the molecules within the workpiece, with the remainder of the power delivered as dipolar molecular rotation.

- Microwave heating is dielectric heating at still higher frequencies. The predominate frequencies used in microwave heating are 915 and 2450 MHz. Microwave heating is 10 to  
10   100 times higher in frequency than the usual dielectric heating, resulting in a lower voltage requirement if the loss factor is constant, though the loss factor is generally higher at microwave frequencies.

- Microwaves can penetrate dielectric materials and be absorbed uniformly, thereby generating heat uniformly. Microwave energy is also selectively absorbed, offering a means  
15   for self-limiting the energy taken up by heterogeneous materials, making overheating less likely. These combined effects allow microwave heating to be more rapid, with less heating of surrounding materials, with a low thermal lag, and therefore with good control.

- A successful energy receptive additive should have a dielectric loss factor, as noted above, that is relatively high. The energy receptive additives useful in this invention typically  
20   can have a dielectric loss factor measured in the RF or microwave frequency of between about 0.5 and 15, more particularly between about 1 and 15, and still more particularly between about 5 and 15. It should be noted that the dielectric loss factor is a dimensionless number.

- Synthetic fibers incorporating energy receptive additives are discussed at greater  
25   length in US Patent Application \_\_\_\_\_, attorney docket number 15708, filed on the same day as this application and co-assigned. Briefly, the fibers have an energy receptive additive capable of dielectric heating and having a dielectric loss of between 0.5

to 15. The fiber more particularly should have a dielectric loss of at least 1 and still more particularly have a dielectric loss of at least 5. It is preferred that the fiber have a dielectric loss tangent of between 0.1 to 1.

more particularly between 0.3 to 0.7.

- 5           The energy receptive additive may be, for example, carbon black, magnetite, silicon carbide, calcium chloride, zircon, magnetite, silicon carbide, calcium chloride, alumina, magnesium oxide, and titanium dioxide. The energy receptive additive may be present in an amount between 2 and 40 weight percent, more particularly between 5 and 15 weight percent. The fiber may also be a bicomponent fiber of the sheath/core or island in
- 10 the sea type. The energy receptive additive may be present in the sheath or core of a sheath/core type bicomponent fiber. The fiber may also a biconstituent fiber. The fiber may be crimped, extendible and/or elastic and the energy receptive additive may be carbon black in an amount between 2 and 40 weight percent.

- 15           In addition to the energy receptive additives discussed above, a number of other polymers and sensitizers may be used. Specifically selecting moieties along the polymer chain and the positioning of moieties along the polymer chain can affect the dielectric loss factor of the polymer and enhance the responsiveness of the polymer to electromagnetic energy. These include polymer composites from blend, block, graft, random copolymers, ionic polymers and copolymers and metal salts. Specific combinations include low density
- 20 PE/polyethylene-polyvinylacetate block copolymer, LDPE/polyethylene glycol, PE/polyacrylates, polyethylene-vinyl acetate copolymer, polyester, polyurethane, polyacrylates, polyethylene glycol (PEG), polyacrylamide (PAA), polyethylenimine (PEEM), polyvinyl acetate (PVAC), polyvinyl alcohol (PVA), PMA-Na, PA-Na, and P(SS-co-MA)-Na, NaCl, CaCl<sub>2</sub>, MgCl<sub>2</sub>, Na<sub>2</sub>CO<sub>3</sub>, Mg acetate, Al acetate and Al (iso-
- 25 peroxide) and polymer of terephthalic acid, adipic acid and 1, 4 butanediol, and polybutylene succinate copolymers..

Fibers having an energy receptive additives are made into webs for use in personal care products by a number of means and subsequently activated. They may be made into a layer and that layer laminated to other layers, the fibers may be intermixed with other materials and deposited as a web as in airforming, or the fibers may be carded  
5 with other fibers. Such other methods and webs as are known in the art are intended to be within the scope of this invention.

One particularly useful example of a material containing fibers with energy receptive additives is a mixture of such fibers, superabsorbent materials (SAM) and natural fibers. An exemplary process for the production and stabilization of the webs of  
10 this invention is that of US Patent Application \_\_\_\_\_, attorney docket 16820, filed on the same day as this application and co-assigned.

The structure this invention may preferably be made by an airforming method. The composition of such a structure may be from about 1 to about 60 weight percent low melting point fiber, from about 0 to about 80 weight percent superabsorbent, and  
15 from about 5 to about 98 weight percent natural fibers. More particular embodiments have from about 4 to 12 weight percent low melting point fiber, 30 to 70 weight percent superabsorbent and 30 to 70 weight percent natural fiber. The nonwoven fibrous structure thus produced may have a basis weight within the range of about 30 - 2500 gsm. The average basis weight of the fibrous structure can alternatively be  
20 within the range of about 50 - 2000 gsm, and can optionally be within the range of about 100 - 1500 gsm.

In the airlaying process a number of layers may be produced, the number of layers being set by the equipment constraints as most airlaying equipment currently available has at most four banks of airlaying heads. In such a case many of the  
25 properties of the web may be varied in the three dimensions of the web. The composition of the web, for example, may be varied in the Z-direction, and more or less binder fiber, natural fibers or superabsorbent place in the bottom or top areas of

the web. The composition may likewise be varied in the X-Y plane across the width of the web, producing areas rich or poor in binder fiber, natural fibers or superabsorbent where desired by the producer.

In a similar manner, the density, basis weight and other properties of the web may be selected in order to produce a web that will most advantageously and cost-effectively meet the needs of the producer.

The fibrous web can be configured to have a varying, contoured basis weight with one or more high basis weight regions, and one or more low basis weight regions. In at least one high basis weight region, at least a significant portion of the fibrous web can have a composite basis weight which is at least about 700 gsm. The high basis weight region can alternatively have a basis weight of at least about 750 gsm, and can optionally have a basis weight of at least about 800 gsm to provide improved performance. In other aspects, the high basis weight region of the fibrous web can have a composite basis weight of up to about 2500 gsm, or more. The high basis weight region can alternatively have a basis weight of up to about 2000 gsm, and can optionally have a basis weight of up to about 1500 gsm to provide desired performance.

Additionally, in at least one low basis weight region, at least a significant portion of the fibrous web can have a composite basis weight is at least about 50 gsm. The low basis weight region can alternatively have a basis weight of at least about 100 gsm, and can optionally have a basis weight of at least about 150 gsm to provide improved performance. In another alternative, the low basis weight region of the fibrous web can have a composite basis weight of up to about 700 gsm, or more. The low basis weight region can alternatively have a basis weight of up to about 600 gsm, and can optionally have a basis weight of up to about 500 gsm to provide desired performance.

In still another aspect, the fibrous web can include an amount of binder fibers which is at least about 0.5 weight percent, as determined with respect to the total weight of the fibrous web. The amount of binder fibers can alternatively be at least about 1

weight percent, and can optionally be at least about 3 weight percent to provide improved performance. In other aspects, the amount of binder fibers can be up to a maximum of about 30 weight percent, or more. The amount of binder fibers can alternatively be up to about 20 weight percent, and can optionally be up to about 10 weight percent to provide

5 an improved performance.

In a further aspect, the fibrous web departing the forming surface can be configured to have a density which is at least a minimum of about 0.01 g/cc, as determined at a restraining pressure of 1.38 KPa (0.2 psi). The density can alternatively be at least about 0.02 g/cc, and can optionally be at least about 0.03 g/cc to provide

10 improved performance. In other aspects, the density of the fibrous web can be up to a maximum of about 0.12 g/cc, or more. The density can alternatively be up to about 0.11 g/cc, and can optionally be up to about 0.1 g/cc to provide improved effectiveness.

The fibrous web can be configured to be a substantially continuous, and substantially flat fibrous web. The fibrous web may be formed with substantially non-

15 contoured, generally straight side edge regions, and with a substantially non-contoured thickness dimension. Additionally, the fibrous web may have a substantially uniform basis weight distribution.

In an alternative arrangement, the fibrous web can be configured to be a substantially continuous fibrous web which has been formed with substantially non-

20 contoured side edge regions and with a selectively contoured thickness dimension. Accordingly, portions of the fibrous web can have a relatively lower thickness, and other portions of the fibrous web can have a relatively higher thickness. Additionally, portions of the fibrous web can have a relatively lower basis weight, and other portions of the fibrous web can have a relatively higher basis weight.

25 The fibrous web can be configured to be a discontinuous fibrous web which includes a serial plurality of separated web portions or segments. The separated portions of the discontinuous fibrous web can each be formed with substantially non-contoured,

generally straight and generally parallel side edge regions. Additionally, each of the separated portions of the formed web can have a generally flat, and substantially non-contoured thickness dimension.

In another arrangement, the fibrous web can be configured to be a discontinuous fibrous web which has been formed with substantially non-contoured side edge regions and with a selectively contoured thickness dimension. Each separated portion of the discontinuous fibrous web can have a relatively-lower thickness region, and a relatively-higher thickness region. Additionally, each separate portion of the discontinuous fibrous web can have a relatively lower basis weight region, and a relatively higher basis weight region.

The fibrous web can be configured to be a substantially continuous fibrous web which has been formed with selectively contoured side edge regions and with a substantially non-contoured thickness dimension. The side edge regions of the fibrous web can be laterally contoured with a selected, undulating, serpentine outline shape.

In an alternative arrangement, the fibrous web can be configured to be a substantially continuous fibrous web which has been formed with selectively contoured side edge regions and with a selectively contoured thickness dimension. Accordingly, predetermined portions of the fibrous web can have a relatively lower thickness, and other portions of the fibrous web can have a relatively higher thickness. Additionally, portions of the fibrous web can have a relatively lower basis weight, and other portions of the fibrous web can have a relatively higher basis weight.

The fibrous web can be configured to be a discontinuous fibrous web which includes a serial plurality of separated web portions or segments. The separated portions of the discontinuous fibrous web can each be formed with laterally shaped side edge regions. Additionally, each of the separated web portions can be formed and with a generally flat and substantially non-contoured thickness dimension.

In still another arrangement, the fibrous web can be configured to be a discontinuous fibrous web which has been formed with selectively contoured side edge regions and with a selectively contoured thickness dimension. Accordingly, predetermined regions of each laterally shaped segment of the discontinuous fibrous web can have a relatively lower thickness, and other regions of each laterally shaped segment of the fibrous web can have a relatively higher thickness. Additionally, predetermined regions of each laterally shaped segment of the discontinuous fibrous web can have a relatively lower basis weight, and other regions of each segment of the discontinuous fibrous web can have a relatively higher basis weight.

The fibrous web can be configured to provide a fibrous web segment or pad in which the binder fiber is more heavily concentrated in a fibrous web stratum that was located relatively closer to and generally adjacent the forming surface employed by the method and apparatus. Accordingly, the web stratum that was closer to the forming surface, with the relatively higher concentration of binder fiber, can have a relatively higher strength, as compared to the other portions of the web.

The fibrous web can be configured to provide a fibrous web segment or pad in which the binder fiber is more heavily concentrated in a fibrous web stratum that was located relatively farther from the employed forming surface and relatively closer to and generally adjacent a free-surface side of the formed web. Accordingly, the web stratum that was farther from the forming surface, with the relatively higher concentration of binder fiber, can have a relatively higher strength, as compared to the other portions of the web.

The fibrous web can be configured to be a fibrous web segment or pad in which the binder fiber is more heavily concentrated in an intermediate-level fibrous web stratum and can optionally be configured to be a fibrous web segment or pad in which a first concentration of binder fiber is located in a first fibrous web stratum, and a different, second concentration of binder fiber is located in a second fibrous web



stratum. Additionally, the binder fiber type may be different in different stratum of the web.

After the fibrous web is produced by, for example, the airforming process, a web transporter can deliver the fibrous web to a binder activation system. The activation system generally has an activation chamber that can produce a standing wave. In a particular feature, the activation chamber can be configured to be a resonant chamber. Examples of suitable arrangements for the resonant, activation chamber system are described in a U.S. Patent No. 5,536,921 entitled SYSTEM FOR APPLYING MICROWAVE ENERGY IN SHEET-LIKE MATERIAL by Hedrick et al. which has an issue date of July 16, 1996; and in U.S. Patent No. 5,916,203 entitled COMPOSITE MATERIAL WITH ELASTICIZED PORTIONS AND A METHOD OF MAKING THE SAME by Brandon et al which has a issue date of June 29, 1999.

The total residence time within the activation chamber or chambers can provide a distinctively efficient activation period. In a particular aspect, the activation period can be at least a minimum of about 0.002 sec. The activation period can alternatively be at least about 0.005 sec, and can optionally be at least about 0.01 sec to provide improved performance. In other aspects, the activation period can be up to a maximum of about 3 seconds. The activation period can alternatively be up to about 2 sec, and can optionally be up to about 1.5 sec to provide improved effectiveness.

The activation of the binder fibers and/or other web materials to form the desired stabilized structures can be performed at higher speed, and can be conducted with shorter activation times, than conventional infrared/convection heating, as noted above. For example, the activation can be conducted with shorter heating times and shorter cooling times. Additionally, the activation operation can be quickly turned on and off, as desired to accommodate any stops and starts of the method and apparatus. As a result, the activation operation can be conducted along a distinctively short length of processing space. This can allow a more compact arrangement, that can be more readily

incorporated into an on-line manufacturing process. In particular configurations, the method and apparatus can produce an airlaid, stabilized fibrous web that has a selectively contoured basis weight and/or a selectively contoured shape. Additionally, the process and apparatus can more efficiently provide a stabilized web having a selectively contoured density. The process and apparatus can also more efficiently provide a stabilized web having a contoured cross-directional width, wherein the width of the stabilized web can vary between relatively wide and relatively narrow, as one moves along a longitudinal length of the web.

The great flexibility of the airforming process combined with the flexibility of the electromagnetic activation system, can allow product designers much leeway in the design of personal care products.

The heating and melt activation of the binder fibers can be produced by any electromagnetic mechanism that is available in the fibrous web. The electromagnetic energy (e.g. microwave energy) may, for example, heat any water vapor that is present within the fibrous web, and the heated or superheated vapor can melt the binder fibers. In another mechanism, the energy can be absorbed by the binder fibers and the absorbed energy can heat and melt the binder fibers. The melted binder fibers can then adhere or bond and connect to the natural fibers. Additionally, the binder fibers can adhere or otherwise bond and interconnect with other fibers and superabsorbent materials that are present within the fibrous web. The method and apparatus can advantageously activate the binder fibers substantially without heating up the entire mass of the fibrous web. In a particular feature, the binder fibers can be rapidly activated while substantially avoiding any excessive burning of the fibrous web.

Superabsorbents that are useful in the present inventions can be chosen from classes based on chemical structure as well as physical form. These include superabsorbents with low gel strength, high gel strength, surface cross-linked superabsorbents, uniformly cross-linked superabsorbents, or superabsorbents with varied

cross-link density throughout the structure. Superabsorbents may be based on chemistries that include poly(acrylic acid), poly(iso-butylene-co-maleic anhydride), poly(ethylene oxide), carboxy-methyl cellulose, poly(-vinyl pyrrolidone), and poly(-vinyl alcohol). The superabsorbents may range in swelling rate from slow to fast. The

5 superabsorbents may be in the form of foams, macroporous or microporous particles or fibers, particles or fibers with fibrous or particulate coatings or morphology. The superabsorbents may be in the shape of ribbons, particles, fibers, sheets or films. Superabsorbents in the form of particles are preferred for the practice of this invention. Superabsorbents may be in various length and diameter sizes and distributions. The

10 superabsorbents may be in various degrees of neutralization. Counter-ions are typically Li, Na, K, Ca.

An exemplary superabsorbent was obtained from Stockhausen, Inc and is designated FAVOR® SXM 880. Another example of these types of superabsorbents may be obtained from the Dow Chemical Company under the name DRYTECH® 2035. An

15 example of fibrous superabsorbents may be obtained from Camelot Technologies, Ltd., of High River, Alberta, Canada and is designated FIBERDRI® 1241. Another Example included in these types of superabsorbents is obtained from Chemtall Inc. of Riceboro, GA, and is designated FLOSORB 60 LADY®, also known as LADYSORB 60®. Additional types of superabsorbents not listed here which are commonly available and known to

20 those skilled in the art can also be useful in the present inventions.

Natural fibers include wool, cotton, bagasse fibers, milkweed fluff fibers, wheat straw, kenaf, hemp, pineapple leaf fibers, peat moss flax and wood pulp. Wood pulps include standard softwood fluffing grade such as NB-416 (Weyerhaeuser Corporation, Tacoma, Washington) and CR-1654 (US Alliance Pulp Mills, Coosa, Alabama), bleached

25 kraft softwood or hardwood, high-yield wood fibers, ChemiThermoMechanical Pulp fibers and Bleached Chemithermal Mechanical Pulped (BCTMP). Pulp may be modified in order to enhance the inherent characteristics of the fibers and their processability. Curl may be

imparted to the fibers by methods including chemical treatment or mechanical twisting.

Curl is typically imparted before crosslinking or stiffening. Pulps may be stiffened by the use of crosslinking agents such as formaldehyde or its derivatives, glutaraldehyde, epichlorohydrin, methylolated compounds such as urea or urea derivatives, dialdehydes

5 such as maleic anhydride, non-methylolated urea derivatives, citric acid or other polycarboxylic acids. Some of these agents are less preferable than others due to environmental and health concerns. Pulp may also be stiffened by the use of heat or caustic treatments such as mercerization. Examples of these types of fibers include NHB416 which is a chemically crosslinked southern softwood pulp fibers which enhances  
10 wet modulus, available from the Weyerhaeuser Corporation of Tacoma, WA. Other useful pulps are debonded pulp (NF405) also from Weyerhaeuser. HPZ3 from Buckeye Technologies, Inc of Memphis, TN, has a chemical treatment that sets in a curl and twist, in addition to imparting added dry and wet stiffness and resilience to the fiber. Another suitable pulp is Buckeye HPF2 pulp and still another is IP SUPERSOFT® from  
15 International Paper Corporation. Suitable rayon fibers are 1.5 denier Merge 18453 fibers from Tencel Incorporated of Axis, Alabama.

Regardless of the manner of making the absorbent structure more receptive to microwaves, the resultant bonded structure has unique physical characteristics that indicate the bonding method. A structure bonded in a conventional thermal process,  
20 i.e., by convection or infrared radiant heat transfer, for example, will exhibit a heating gradient where the greatest heating occurs on the exterior or extremities decreasing with depth to a minimum at the center. For this heating process the greater oxidation of the fibers occurs on the outside of the structure, since heating by convection and conduction occurs from the outside of the structure toward the center. Dielectric  
25 heating, i.e., heating by Radio frequency or microwave radiation, creates a heating gradient whereby the maximum heating occurs from the center of the structure, decreasing towards the outer extremities, making oxidation of the outer fibers less

than that of heating by convection or infrared radiant heat transfer. Conventional thermal bonding also results in some yellowing of the outer fibers that is not apparent in Radio frequency or microwave radiation heating. Lastly, dielectric heating results in a structure that is more uniformly bonded than the same structure bonded by convection or convection or infrared radiant heat transfer. The absorbent structure of this invention is therefore, relatively uniformly bonded from the center (when compared to the same structure bonded by conventional thermal convection and infrared radiant heat transfer means). The heating occurs at a faster rate using the dielectric heating and the oxidative processes causing yellowing and discoloration are therefore minimized and the bonding structural integrity at the center regions of the heated material is maximized. The microwave heating will occur in from 5 to 30 percent of the rate required for convection or infrared radiant heat transfer reducing the time at elevated temperature.

For convection and infrared radiant heat transfer any liquid water within the matrix moves toward the surface of the fibrous matrix and bulk structure at the water diffusion rate of the structure itself. The passive diffusion rate is proportional to the material matrix density. In contrast, dielectric heating raises the internal temperature rapidly driving water to the outside surface via an active transport. Thus the overall transfer of heat from the water to the surrounding material occurs actively not passively. The end result is more rapid and uniform heating of the structure. A factor having a large effect on the dielectric heating properties of the matrix, given a specific structure, is the water content and distribution. The active transport of the water provides a more uniform distribution of the heating throughout the structure.

The various structures provided using different heating techniques are qualified and quantified using measurements of location and degree of oxidation and bonding efficiency within the polymer blend matrix. Techniques such as ultraviolet, visible, near infrared, infrared and Raman spectroscopy; surface analysis; differential

scanning calorimetry; chromatographic separation; and various microscopic techniques can demonstrate the unique properties of materials heated “externally” via convection or infrared radiant heat transfer, versus “internal” heating using dielectric techniques.

5           With infrared and convection heating the radiant energy is directly translated to heat at the surface layers where the surface temperature rises rapidly. The heat created at the outer surfaces eventually diffuses by thermal conduction toward the center. This heating process is relatively slow and it takes significant time for the center of a structure to reach the threshold temperature necessary to begin to melt the binder fibers. The

10   slow process of thermal conduction is dependent upon the thermal conductivity of the structure and its overall dimensions (thickness). For dielectric heating the peak temperature is also near the surface but the temperature rise at the center is nearly identical to the outer surface-heating rate. This occurs since the dielectric heating process is active and direct. This direct transfer of energy to the center of an object is

15   less dependent upon thermal conductivity and more dependent upon the dielectric field strength and dielectric properties of the material. For a comparison of the heating depth profiles for infrared/convection versus dielectric heating see Figure 1. This figure illustrates the spatial areas in a structure where direct heating occurs. In Figure 1, the temperature in °C is on the Y-axis, the first surface is on the left side and the second

20   surface on the right side with the material’s center centered between the two surfaces. The dashed line indicates the heating profile for dielectric heating and the solid line indicates the heating profile for infrared/convection heating. As can be seen from Figure 1, there is a much greater variation in the temperature profile for infrared/convection heating than for dielectric heating.

25           In order to achieve the desired equivalent internal temperature, infrared energy must be applied from 3 to 30 times longer than dielectric heating. This extended heating is required in order to attain a pre-specified temperature threshold at the center. When

properly applied, dielectric heating occurs rapidly and more uniformly. The rapid and uniform direct heating prevents large-scale thermal degradation of polymers within heated structures.

The percent oxidation occurring for any given structure is proportional to the time exposure of the polymer to air at an elevated temperature (i.e., above 75 °C). Infrared heating maintains a higher surface temperature throughout the heating cycle than microwave heating. The projected percent oxidation from infrared and convection heating will be from 5 to 35 (or more) times greater at the surface than it would be at the surface in dielectric heating. Heating by microwave radiation will, therefore, produce a structure having less than 5 times more oxidation at its outer surface than at its center and more particularly less than 3 times more oxidation at its outer surface than at its center.

A typical comparison of the total oxidation/degradation occurring to polymer samples heated using infrared/convection heating versus dielectric heating is illustrated in Figure 2. In Figure 2, the percentage of oxidation is on the Y-axis, the first surface is on the left side and the second surface on the right side with the material's center centered between the two surfaces. The dashed line indicates the oxidation profile for dielectric heating from surface to surface and the solid line indicates the oxidation profile for infrared/convection heating. As can be seen from Figure 2, there is a much greater variation in the oxidation profile for infrared/convection heating than for dielectric heating. (Note: Improper use of any known heating technique will cause rapid degradation and destruction of the material being heated.)

Large differences in oxidative degradation due to surface heating are easily measured using the analytical techniques previously described. For this application, typical compounds resulting from oxidative degradation include the existence of highly colored (high molar absorptivity) species. These colored compounds result from the formation of identifiable unsaturation. Examples include polyenes, unsaturated ketones, carboxyl-containing organic chains, quinones, and in general compounds with

conjugated double bonds formed by the oxidation/degradation mechanisms of free radical formation, elimination reactions, and random chain scission. Often the increased oxidation can readily be observed with the unaided eye, making the materials heated using infrared and convection heating appear more yellow and thus of perceived lower quality.

A rapid, non-destructive method to analyze polyolefins and cellulosic materials for the presence of compounds resulting from thermal degradation is described. The ultraviolet and visible spectrum is measured on a control and heated sample. The resulting spectra are subtracted and the difference spectra compared to a series of reference sample spectra prepared by heating a series of comparison samples at elevated temperatures for different known periods to bracket the heating application. The spectra yield direct information on the color and molecular absorptive properties of the thermal degradation products present in polymers and cellulose. The ratios of the absorbance maximum for the ultraviolet versus the visible spectrum yields precise information on the chemical species present and on the approximate concentrations. This basic procedure can be reproduced using ultraviolet and visible fluorescence, Raman spectroscopy, and infrared spectroscopy for similar and complementary results.

For more detailed structural analysis, the polymer and cellulosic materials can be dissolved in appropriate solvents, subjected to liquid chromatographic separation, and further analyzed using either the spectroscopic techniques described above or by mass spectrometry to determine the structure and molecular weight of any degradation compounds. These compounds are often highly colored as yellow or brown due to the browning effect of thermal degradation oxidation. There is a plethora of literature describing the detailed analysis of degradation compounds in synthetic and natural polymers and most of these techniques are quite sufficient for measuring the relative amount of oxidation throughout the cross-section of the heated structure. In addition, the use of scanning electron microscopy with osmium tetroxide staining



will reveal the integrity of bond points within the structure indicating the maximum heating temperature reached in any portion of the heated structure during the process.

As will be appreciated by those skilled in the art, changes and variations to the invention are considered to be within the ability of those skilled in the art. Examples of  
5 such changes and variations are contained in the patents identified above, each of which is incorporated herein by reference in its entirety to the extent consistent with this specification. Such changes and variations are intended by the inventors to be within the scope of the invention.